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THESIS

MINIMIZING ARMY CADET TEMPORARY DUTY

by

Clay S. Chilson

March, 1998

Thesis Advisor: Robert F. Dell
Second Reader: Charles H. Shaw

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Every newly-commissioned Army officer from a Reserve Officer Training Corps (ROTC) commissioning source joins one of 19 different basic branches (e.g., infantry, armor) and undergoes initial training to develop fundamental skills at an Officer Basic Course (OBC). Each basic branch has a separate training program and offers multiple OBC classes every year. The Army grants commissions to approximately 3,000 ROTC cadets annually and, under the current system, manually schedules each cadet to attend an OBC class. In addition, the Army schedules approximately 850 of these cadets to fill one of two temporary duty (TDY) assignments en route to their OBC class. This thesis develops a mixed integer linear program called Minimizing Cadet Temporary Duty (MCTDY) to reduce the time needed to schedule cadets and reduce the TDY costs as well as pay and allowances incurred by all 2Lts prior to their OBC class. For 2,828 cadets receiving commissions in 1998, MCTDY produces face-valid, cost-effective results. Direct comparisons between MCTDY and manual schedules are not made but experiments with MCTDY indicate a difference in TDY costs of up to $15 million is possible.

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MINIMIZING ARMY CADET TEMPORARY DUTY

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B.S., United States Naval Academy, 1992

Submitted in partial fulfillment of the
requirements for the degree of

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ABSTRACT

Every newly-commissioned Army officer from a Reserve Officer Training Corps (ROTC) commissioning source joins one of 19 different basic branches (e.g., infantry, armor) and undergoes initial training to develop fundamental skills at an Officer Basic Course (OBC). Each basic branch has a separate training program and offers multiple OBC classes every year. The Army grants commissions to approximately 3,000 ROTC cadets annually and, under the current system, manually schedules each cadet to attend an OBC class. In addition, the Army schedules approximately 850 of these cadets to fill one of two temporary duty (TDY) assignments en route to their OBC class. This thesis develops a mixed integer linear program called Minimizing Cadet Temporary Duty (MCTDY) to reduce the time needed to schedule cadets and reduce the TDY costs as well as pay and allowances incurred by all 2Lts prior to their OBC class. For 2,828 cadets receiving commissions in 1998, MCTDY produces face-valid, cost-effective results. Direct comparisons between MCTDY and manual schedules are not made but experiments with MCTDY indicate a difference in TDY costs of up to $15 million is possible.

TABLE OF CONTENTS

I. BACKGROUND 1

A. INTRODUCTION 1

B. ROTC CHAIN OF COMMAND 2

1. Cadet Command, Regional Headquarters and Brigades 2

2. ROTC Battalions and Extension Centers 2

3. Individual Cadet 4

C. SCHEDULING CONSIDERATIONS 6

1. TDY Assignments 6

a. Camp LT 6

b. Gold Bar Recruiter 8

2. First Assignments 8

3. Graduation Leave 9

4. Travel Time 9

5. "Slack Day" 9

D. CURRENT SCHEDULING PROCESS 10

E. SCHEDULING OBJECTIVES 11

F. MOTIVATION FOR A COMPUTER MODEL 12

G. THESIS OUTLINE 12

II. RELATED STUDIES 13

III. MCTDY DEVELOPMENT AND IMPLEMENTATION 21

A. MCTDY OVERVIEW 21

B. MIP FORMULATION 22

1. Indices 22
2. Index Sets 22
3. Given Data (units) 22
4. Derived Data (equation) 24
5. Binary Variables 24
6. Non-Negative Variables 24
7. Formulation 25
8. Explanation of Objective Function and Constraints 26

C. OBJECTIVES OF PROGRAMMING CODE FOR GBR SCHEDULING 28
D. SCHEDULING CADETS TO GBR ASSIGNMENTS 29
1. Given Data (units) 29
2. Data Derived in Pseudo Code (units) 30
3. Data Derived From MIP (equation) 30
4. Pseudo Code 31
E. MCTDY IMPLEMENTATION 32

IV. INPUT DATA AND COMPUTATIONAL RESULTS 33
A. DATA CONTAINED IN INPUT TABLES 33
B. OVERVIEW OF MCTDY TEST DATA 35
C. COMPUTATIONAL RESULTS 37

V. CONCLUSIONS AND FUTURE ENHANCEMENTS 41

LIST OF REFERENCES 43

INITIAL DISTRIBUTION LIST 45

EXECUTIVE SUMMARY

Every newly-commissioned Army officer from a Reserve Officer Training Corps (ROTC) commissioning source joins one of 19 different basic branches (e.g., infantry, armor) and undergoes initial training to develop fundamental skills at an Officer Basic Course (OBC). Each basic branch has a separate training program and offers multiple OBC classes every year. The Army grants commissions to approximately 3,000 ROTC cadets annually and, under the current system, manually schedules each cadet to attend an OBC class. In addition, the Army schedules approximately 850 of these cadets to fill one of two temporary duty (TDY) assignments en route to their OBC class.

Cadet Command oversees the scheduling of ROTC cadets to OBC classes and will soon have financial responsibility for TDY costs (includes per diem and travel costs) incurred by 2Lts en route to their OBC class. Cadet Command desires a computer model to:

1. reduce the time to develop a schedule. ROTC representatives currently invest approximately 600 man-hours annually to schedule cadets to their OBC.
2. develop a cost-effective schedule. For each day of reduction in the average TDY per 2Lt, there would be a savings of approximately $225,000.

This thesis develops a mixed integer linear program called Minimizing Cadet Temporary Duty (MCTDY) to reduce the time needed to schedule cadets and reduce the TDY costs as well as pay and allowances incurred by all 2Lts prior to their OBC class. MCTDY produces a 1998 schedule that is face-valid, meets all scheduling objectives, and solves in approximately 73 minutes on an IBM RS/6000 Model 595 Workstation. Direct comparisons between MCTDY and manual schedules are not made but experiments with MCTDY indicate a difference in TDY costs of up to $15 million is possible.

MCTDY proves useful in determining the consequences of policy changes. For example, Cadet Command may consider a policy that guarantees each cadet's requested graduation leave. The 1998 schedule with the best balance of all measures of performance grants 75.3% of cadets' requested graduation leave. If 99.6% of the cadets' requested graduation leave was granted, then TDY would increase by more than 10 days per cadet at a cost of more than $2 million.

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I. BACKGROUND

A. INTRODUCTION

Every newly-commissioned Army officer from a Reserve Officer Training Corps (ROTC) commissioning source joins one of 19 different basic branches (e.g., infantry, armor) and undergoes initial training to develop fundamental skills at an Officer Basic Course (OBC). Each basic branch has a separate training program, most at different locations, and offers multiple OBC classes every year. The Army grants commissions to approximately 3,000 ROTC cadets[1] annually and, under the current system, manually schedules each cadet to attend an OBC class. In addition, the Army schedules approximately 850 of these cadets to fill one of two temporary duty (TDY) assignments en route to their OBC class. This thesis develops a mixed integer linear program called Minimizing Cadet Temporary Duty (MCTDY) to reduce the time needed to schedule cadets and reduce the TDY costs as well as pay and allowances incurred by all 2Lts prior to their OBC class.

[1] This thesis uses *cadet* and *2nd Lieutenant* (2Lt) to distinguish between different stages of an Army career. A cadet attends an Army ROTC commissioning source and receives the rank 2Lt at his/her commissioning ceremony which immediately follows college graduation. The Army *schedules* cadets to various assignments; 2Lts *serve* in these assignments.

B. ROTC CHAIN OF COMMAND

1. Cadet Command, Regional Headquarters and Brigades

Cadet Command, located in Fort (Ft.) Monroe, VA (Figure 1), oversees the scheduling of ROTC cadets to OBC classes. Under Cadet Command, three regional headquarters (for historic reasons called Region 1, Region 2, and Region 4) have administrative responsibility for ROTC battalions and extension centers in the United States (US), Puerto Rico, and Guam. Region 1 covers ROTC battalions and extension centers in the eastern portion of the US and Puerto Rico; Region 2 covers ROTC battalions and extension centers in the central portion of the US; Region 4 covers ROTC battalions and extension centers in the western portion of the US and Guam. Figure 1 shows the areas of responsibilities within the US for each regional headquarters. Under each regional headquarters, several ROTC brigades have administrative responsibility for approximately 15-20 ROTC battalions and extension centers within their geographic area of responsibility.

2. ROTC Battalions and Extension Centers

The next level in the ROTC chain of command is the ROTC battalion or ROTC extension center. There are approximately 255 universities and colleges throughout the US, Puerto Rico, and Guam with Army ROTC battalions and another 15 universities and colleges with extension centers. Extension centers typically have smaller cadet enrollments than battalions and conduct ROTC

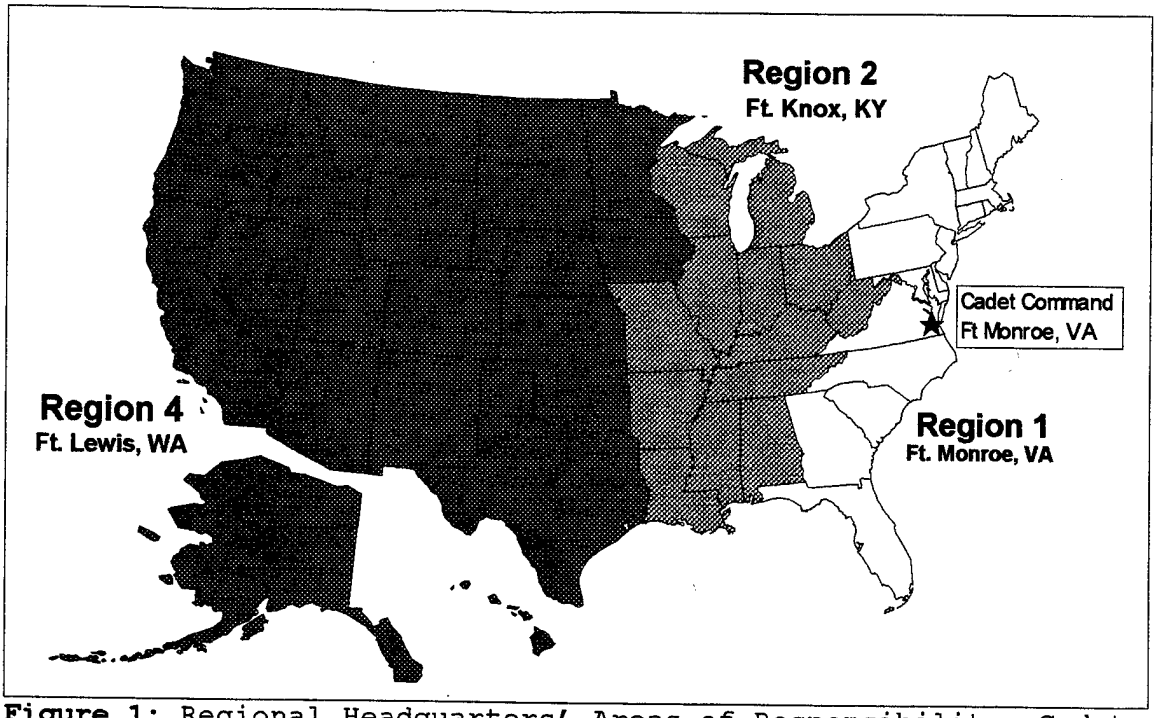

Figure 1: Regional Headquarters' Areas of Responsibility. Cadet Command holds overall administrative responsibility for Army ROTC battalions and extension centers. Under Cadet Command, three regional headquarters divide administrative responsibility.

training with battalions in their local geographic area. Each ROTC battalion and extension center is identified by a unique six-digit number called a Federal Interagency Committee on Education (FICE) code. The Professor of Military Science, typically an Army Lieutenant Colonel at battalions and a Major at extension centers, heads his/her ROTC command. Figure 2 shows both the dispersion and density of ROTC battalions and extension centers throughout the US. Each dot in Figure 2 represents the existence of an ROTC battalion or extension center within the state in which it's shown but not necessarily its exact location.

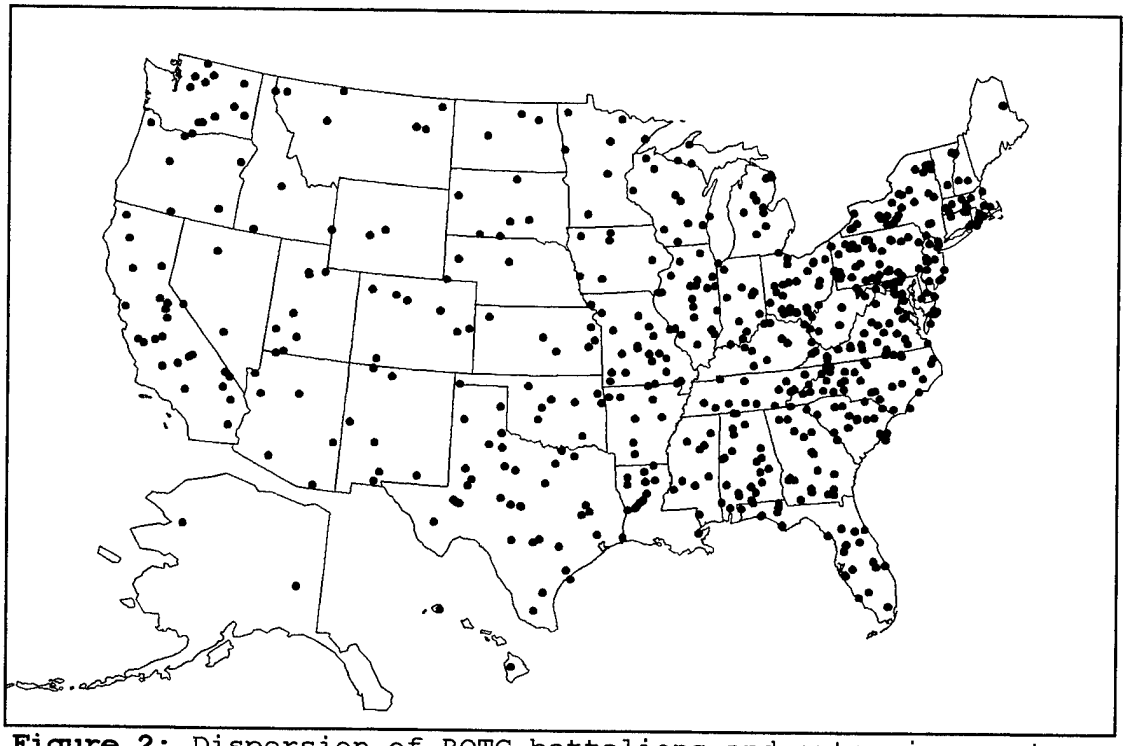

Figure 2: Dispersion of ROTC battalions and extension centers.

3. Individual Cadet

The final level in the ROTC chain of command is the individual cadet. During fiscal year (FY) 1997, approximately 500 cadets graduated during the fall semester and approximately 2,500 cadets graduated during the spring semester. During the cadets' final year in college, they submit their preferences for basic branch selection. Table 1 lists the 19 basic branch selections available to each ROTC cadet, the respective OBC training location, and the number of OBC classes offered in each basic branch for cadets receiving commissions between 03 January 1998 and 31 September 1998.

BASIC BRANCH (ABBREVIATION)		OBC LOCATION	Classes
Air Defense	(AD)	Ft. Bliss, TX	7
Adjutant General	(AG)	Ft. Jackson, SC	6
Army Nurse	(AN)	Ft. Sam Houston, TX	0
Armor	(AR)	Ft. Knox, KY	19
Aviation	(AV)	Ft. Rucker, AL	43
Chemical	(CM)	Ft. McClellan, AL*	10
Engineer	(EN)	Ft. Leonard Wood, MO	18
Field Artillery	(FA)	Ft. Sill, OK	11
Finance	(FI)	Ft. Jackson, SC	3
Infantry	(IN)	Ft. Benning, GA	12
Military Intelligence	(MI)	Ft. Huachua, AZ	16
Military Police	(MP)	Ft. McClellan, AL*	12
Medical Service	(MS)	Ft. Sam Houston, TX	3
Medical Service (Special)	(MSD)	Ft. Sam Houston, TX	0
Ordnance	(OD)	Redstone Arsenal, AL	15
Ordnance (Special)	(ODD)	Aberdeen Proving Ground, MD	5
Quartermaster	(QM)	Ft. Lee, VA	11
Signal Corps	(SC)	Ft. Gordon, GA	9
Transportation Corps	(TC)	Ft. Eustis, VA	10

Table 1. Army basic branches available to ROTC cadets, the respective OBC training location, and the number of OBC classes offered for cadets receiving commissions between 03 January and 31 September 1998. *Chemical and Military Police basic branches start conducting OBC training at Ft. Leonard Wood in FY 1999.

Prior to the commissioning ceremony, the Army assigns either an immediate active (IA) or an active (AD) duty status

designation to each cadet. A cadet's duty status designation determines when he or she starts receiving officer pay. The Army starts paying IA 2Lts immediately after graduation leave; however, AD 2Lts do not receive pay until they actually report for their first assignment.

C. SCHEDULING CONSIDERATIONS

1. TDY Assignments

In addition to scheduling cadets to OBC classes, Cadet Command schedules some cadets to either a Camp Lieutenant (Camp LT) or a Gold Bar Recruiter (GBR) TDY assignment. These assignments occur after a 2Lt's commissioning ceremony but prior to his/her OBC class and are considered TDY since they are less than 180 days in length. A 2Lt can not serve as both a Camp LT and a GBR.

a. Camp LT

The ROTC community uses basic and advanced summer camps as one method of training cadets in Army fundamentals. Approximately half the cadets attend the basic summer camp and all cadets must attend the advanced summer camp prior to receiving a commission. Cadets usually attend the basic camp the summer following their sophomore year and the advanced camp the summer following their junior year. Cadets who complete

specified ROTC courses during their first two years of college are not required to attend the basic camp. The Army conducts the basic camp in Ft. Knox, KY and the advanced camp in Ft. Lewis, WA.

Camp LTs serve as the operational and administrative support personnel for both summer camps. During FY 1998, the Army requires 463 2Lts to serve in Camp LT assignments. Camp LT assignments vary by both start date and length of service; there are more than 40 different combinations for FY 1998. Cadet Command uses six rules and guidelines to schedule Camp LTs:

1. Fill all assignments set forth by staffs at Ft. Lewis and Ft. Knox.
2. Use cadets in all basic branches of the Army except Medical Service, Medical Service (Special), and Army Nurse.
3. Use cadets from all universities except those in Puerto Rico.
4. Use cadets graduating in the Spring semester only.
5. Meet minimum and maximum restrictions established by Cadet Command on the percentage of Camp LTs from each region who serve at each camp location.
6. Strive to use cadets who desire to serve in Camp LT assignments.

b. Gold Bar Recruiter

GBRs remain at their university following the commissioning ceremony to recruit new ROTC members from the student body. GBRs work for the Professor of Military Science as a supplement to his/her staff. Cadet Command uses six rules and guidelines to schedule GBRs:

1. At most one 2Lt from each university can serve as a GBR at a time.
2. A GBR must serve at least 45 days.
3. A GBR can serve no more than 140 days. A GBR serves 140 days as long as it doesn't cause early OBC classes to remain unfilled.
4. The 2Lt must volunteer to serve as a GBR.
5. The Professor of Military Science must recommend the cadet for the GBR assignment.
6. Strive to schedule one of the Professor of Military Science preferences to the GBR assignment.

2. First Assignments

Three assignment sequences exist for 2Lts following their commissioning ceremony: (1) 2Lts may go directly to an OBC class; (2) 2Lts may serve as a Camp LT and then attend an OBC class; or (3) 2Lts may serve as a GBR and then attend an OBC class. Again, the Army does not pay AD 2Lts until the start of their first assignment.

2Lts from other commissioning sources may attend other assignments prior to OBC class. Some of these assignments

include Ranger School, Airborne School, Air Assault School, and Northern Warfare School. Under current Army policy, 2Lts from ROTC commissioning sources may only attend these schools once they've completed an OBC class.

3. Graduation Leave

An IA cadet may request up to 30 days unpaid graduation leave to be taken immediately following his/her commissioning ceremony. Cadet Command grants all graduation leave requested as long as it does not cause an assignment to go unfilled.

4. Travel Time

Cadet Command must provide sufficient time for 2Lts to travel between assignments. For example, a 2Lt commissioned from the Boston College ROTC Battalion may serve as a Camp LT in Ft. Lewis, WA and then attend an Infantry OBC class in Ft. Benning, GA. Without considering travel time in the scheduling process, the 2Lt may be unable to start his/her assignments on time. Many 2Lts from ROTC battalions in Puerto Rico face the additional task of developing English language skills. Cadet Command grants these 2Lts up to 150 travel days prior to starting OBC class to attend an English language proficiency school.

5. "Slack Day"

A "slack day" occurs between a 2Lt's commissioning ceremony and OBC class start date when he/she receives TDY

funds, in addition to pay and allowances, but is not serving as a Camp LT, GBR, or in a travel status. In the next few years, Cadet Command assumes financial responsibility for TDY costs incurred by 2Lts en route to their OBC class and therefore wants to minimize the number of slack days. Although the issue is under debate, Cadet Command currently believes its financial responsibilities will include per diem and travel costs. In this thesis, TDY cost is synonymous with per diem and travel cost.

A 2Lt's duty status designation affects the way slack days are computed. Since the Army starts paying IA 2Lts immediately after their graduation leave, they may incur slack days from after graduation leave until they start their OBC class. Since the Army starts paying AD 2Lts at the beginning of their first assignment, AD 2Lts may only incur slack days following completion of service as a Camp LT or GBR, if assigned, until they start their OBC class.

D. CURRENT SCHEDULING PROCESS

Army ROTC 2Lts constitute approximately 65% of individuals required to attend an OBC class. In addition, the United States Military Academy (USMA), Officer Candidate School (OCS), US Army Reserve, Army National Guard, US Marine Corps, and foreign militaries also send individuals to OBC classes. Cadet Command organizes an annual conference at which each of these seven communities negotiate for OBC class assignments. This

one-week conference takes place in late January or early February.

Once the OBC class assignments have been allocated to each of the seven communities, Cadet Command schedules ROTC cadets to GBR, Camp LT, and OBC assignments. Cadet Command does not currently have a time-efficient or cost-effective scheduling method. Cadet Command simply schedules individuals to assignments manually while ensuring no scheduling conflicts exist.

E. SCHEDULING OBJECTIVES

Cadet Command strives to minimize the number of slack days and achieve four objectives:

1. Satisfy Camp LT scheduling guidelines on page 7.
2. Satisfy GBR scheduling guidelines on page 8.
3. Fill the earliest available OBC classes, when possible. Scheduling cadets to Camp LT assignments may force some early OBC classes to remain unfilled.
4. Grant graduation leave requests to IA cadets, when possible. Cadets scheduled for early Camp LT or OBC class assignments may not receive all requested graduation leave. IA GBRs must request graduation leave from the Professor of Military Science and take graduation leave concurrently with the GBR assignment.

F. MOTIVATION FOR A COMPUTER MODEL

Cadet Command desires MCTDY to accomplish three objectives:

1. Reduce the time to develop a schedule. ROTC representatives currently invest approximately 600 man-hours annually to schedule cadets to their OBC.
2. Reduce TDY costs incurred at scheduling conferences by reducing the number of representatives needed at conferences.
3. Develop a schedule with minimal slack days. Cadet Command conservatively estimates the average TDY cost at $75 per day per 2Lt. With approximately 3,000 ROTC 2Lts produced each year, the command can save nearly $225,000 annually by reducing just one day from the average number of slack days per 2Lt.

G. THESIS OUTLINE

This chapter provides background on the OBC scheduling problem and discusses the need for a computer-generated schedule. Chapter II explores similar scheduling problems. Chapter III develops the mathematical formulation and provides the explanation for each of MCTDY's equations. Chapter IV discusses MCTDY's input data and computational results, and Chapter V states conclusions gained from the computational results.

II. RELATED STUDIES

Scheduling problems commonly arise in both military and civilian organizations and are extensively reported within the Operations Research community. Therefore, researching similar studies may yield valuable insights into the development of MCTDY. This chapter discusses several closely related studies and notes their similarities and differences with the OBC scheduling problem.

Justice (1993) presents a mixed integer linear program (MIP) to aid the Marine Corps' scheduling of courses and students in the communications and electronics Military Occupational Specialty (MOS). The Marines require every entrant to undergo initial training in a series of one or more courses to qualify for service in a specific MOS. Justice determines the course start dates and the number of assignments available in each class. The model minimizes waiting time between successive courses. Due to the size of the model, the MIP initially schedules class start dates to a one-week resolution and then adjusts the starting dates to produce a daily schedule.

Justice uses the General Algebraic Modeling System (GAMS) and the X-System solver to produce a schedule. The 1993 fiscal year has 236 training days and offers 17 different courses from Communications Electronics Maintenance School. The MIP solves in 10 minutes on a 80486 processor and yields a schedule with 62% less delay between courses than the manually created schedule.

All Marine courses follow a specific sequence and each course, except the first course in a sequence, has a unique predecessor course. The OBC scheduling problem, on the other hand, does not have a well-defined progression of assignments. Although all Army 2Lts ultimately attend an OBC, many first serve as either a Camp LT or a GBR. The Marines know which students will attend the various classes; the Army ROTC must decide which cadets serve in various GBR, Camp LT, and OBC assignments.

Another significant difference exists in the start dates of the Marine and Army courses. Justice schedules the start dates while the OBC problem has fixed Camp LT and OBC assignment start dates. Also, Justice accounts for attrition as Marines progress through classes in the sequence. Cadet Command does not require MCTDY to account for cadet attrition. If a cadet becomes unable to start an assignment, Cadet Command manually reschedules another cadet to fill the vacant assignment. Typically, there exists a cadet in the same basic branch, originally scheduled to the last available OBC class, who will be "moved up" to fill the assignment.

Maskos (1991) presents a MIP to schedule Marine recruits to their initial assignment for occupational training. This multi-objective MIP minimizes training time while filling as many assignments as possible with the most qualified persons. The model considers mandatory course prerequisites, desirable course prerequisites, varying priorities to fill different classes, minority distribution policies, and recruiter promises when scheduling Marines to their occupational training.

Minority distribution constraints for each class and constraints for sharing unfilled quotas among classes eliminate the network structure of the initial model. Maskos uses a two-phased approach to convert the integer program into a network model.

The first phase solves the program's LP relaxation and uses the fractionated results to determine upper and lower bounds on minority fill and total fill for each class. The second phase uses the lower and upper bounds to rewrite the constraints and achieve a network model. Maskos then solves the network model using a linear program solver.

The Marine recruit scheduling problem is similar to the OBC scheduling problem in several ways. Both problems schedule new active duty personnel to classes and both must meet population distribution requirements within those classes (Camp LT assignments). However, the OBC scheduling problem requires scheduling some cadets to GBR and Camp LT assignments prior to their OBC assignment. The Marine recruit scheduling problem does not include any such intermediate step.

Bausch et al. (1991) constructs a network optimization algorithm for the efficient assignment of Marine Corps Officers to crisis mobilization assignments. The algorithm requires less than 10 minutes on a 80386 processor to schedule 40,000 officers to 27,000 assignments. The speed allows multiple model runs before the leadership must commit to a decision.

The optimization algorithm has three objectives:

1. Maximize the number of assignments filled by officers with acceptable qualifications.

2. Maximize the number of assignments with officers whose qualifications most closely match those qualifications preferred for the position.
3. Keep as many officers as possible assigned to the same command to prevent unnecessary turmoil.

Explicit consideration of all officer/assignment combinations requires more than 1,000,000,000 arcs in the network. Bausch et al. use many practical refinements to eliminate ineligible officer/assignment pairs and streamline the decision-making process. These refinements include node aggregation of both similar officers and similar duty assignments, arc screening to determine eligible officer/assignment pairs, and separating the problem into subproblems based on assignment priority.

This algorithm is not suitable for the OBC scheduling problem for two reasons. First, the algorithm does not schedule some personnel to intermediate assignments prior to reaching the final duty station. Second, this algorithm is very time-efficient within the network structure of the assignment problem. The OBC problem, however, loses its network structure with the inclusion of constraints on the population distribution requirements with Camp LT assignments.

Cheng (1987) develops a heuristic to schedule commissioned officer assignments in the United States Marine Corps. The first phase of the model schedules the class start dates for officers who are assigned to those classes in the model's second phase. The course scheduling phase (phase 1) uses a FORTRAN 77

implementation of a heuristic to schedule the series of assignments for initial officer training. Some scheduling sequences include as many as three training assignments. Cheng's thesis, like Justice's thesis, has the unique predecessor-successor relationship for training courses. The heuristic schedules the various classes while minimizing officer training time.

The officer assignment phase (phase 2) solves an integer program in GAMS to determine the number of officers assigned from each predecessor class to each successor class. As discussed previously, the OBC scheduling problem does not have this predecessor-successor relationship. Cheng's model also does not schedule specific officers to courses, but only numbers of officers to courses. Because of these reasons, this model also is not appropriate for the OBC scheduling problem.

Liang and Buclatin (1988) develop a network model with side constraints for the US Navy's personnel assignment problem with en route training. During the latter stages of the Cold War era, the Navy sent approximately 200,000 enlisted personnel to new assignments every year. Prior to the sailors' transfers, many did not have the prerequisite skills necessary for their next assignment. To acquire the needed training, the Navy sent over 100,000 sailors each year to technical schools en route to their follow-on assignment. This problem resembles the OBC scheduling problem since some sailors (2Lts) go directly to their next assignment (OBC class) and some go to technical training (TDY assignments) en route to their next assignment (OBC class).

For each technical training class, their is an upper limit on the number of assignments available to sailors; however, not all assignments must be filled. This is slightly different from the OBC scheduling problem since Cadet Command must fill all Camp LT assignments. Also, Cadet Command requires a specific distribution of Camp LTs from each region at each camp location. The enlisted personnel scheduling problem simply maximizes the utility of sending personnel to technical training and follow-on assignments without concern for any distribution requirements.

Liang and Buclatin use a side-constraint network computer code called NETSID to solve the Navy personnel scheduling problem. NETSID is a specialized linear programming code that takes advantage of the underlying network structure in their model. Liang and Buclatin tested their model on one of the nearly 100 different occupations in the Navy, the aviation electronics technicians. The test data included 200 sailors, 230 jobs, and 43 available vacancies in 16 different classes. NETSID ran in about 7 minutes on an IBM 4341/12 which is significantly less time than the one man-week approximately required to manually schedule the same problem. In addition to the time saved, a simulated manual process required 16% more school seats than the schedule NETSID produced.

Liang and Buclatin reported that most top-level managers were very supportive of the computer model. However, some of the operational users, or "detailers", resisted model implementation since they felt it reduced their flexibility, responsibility, and authority over assignment decisions. To meet the detailers desires, Liang and Buclatin gave detailers

control over some of the input files resulting in greater user flexibility to changing policy priorities. Detailers did show a willingness to use the model once their concerns were addressed.

Blanco and Hillery (1994) attest to the resistance offered by the 200 or so Navy enlisted detailers towards the implementation of a personnel assignment model. The resistance was primarily because the model designers did not address the negotiation aspects of the assignment process. Their goal was simply to optimize the personnel/assignment pairings and provide the managers with the change in assignment efficiency due to changes in scheduling policy. This strategy meant detailers simply dictated the sailors' next duty stations without presenting sailors with a number of choices. After nearly nine years from the project's beginning, model designers incorporated changes that were more responsive to the detailers' needs and the Chief of Naval Personnel approved the model for full implementation.

This scenario demonstrates the possibility of developing an OBC scheduling model which satisfies Cadet Command's objectives but is rejected by the schedulers at the regional and brigade levels. However, since cadets must go to the OBC in their respective branch, it is unlikely MCTDY will encounter such strong opposition. The variable that may cause the greatest concern is the amount of graduation leave granted to IA 2Lts. The greatest lesson learned from Blanco and Hillery is to bring those who may present the greatest opposition into the model development process early. By getting inputs from all parties, one increases the chance of the model's success.

Ali et al. (1993) again look at the Navy personnel assignment problem and used a new heuristic which appears capable of satisfying the Camp LT distribution requirement. The algorithm, based on resource-directive decomposition and Langrangian relaxation, was coded in FORTRAN 77 and tested on an IBM 9370.

Despite the existence of an algorithm which appears capable of solving the OBC scheduling problem, this thesis develops a model using GAMS. Brooke et al. (1996) describes GAMS as a model generator and solver interface used for linear, nonlinear, and integer programming. GAMS generates mathematical models using algebraic statements which are easily read, modified, and transported from one computer to another. Should practical limitations prevent the use of GAMS, further investigation into the heuristic developed by Ali et al. could be conducted. The following chapter develops the mathematical model for the OBC scheduling problem.

III. MCTDY DEVELOPMENT AND IMPLEMENTATION

A. MCTDY OVERVIEW

MCTDY consists of a MIP and some post-processing programming code. The MIP input data includes pertinent cadet information, Camp LT requirements, and the number of assignments at each OBC class. The MIP output includes the optimal schedule for filling Camp LT and OBC assignments and serves as input to the post-processing programming code. The post-processing programming code uses the MIP output to schedule cadets to GBR assignments.

Scheduling GBR assignments separately from the MIP significantly reduces both the size of MIP and the time required to solve it. This simplification still accomplishes Cadet Command's objectives because of the secondary GBR assignment priority. Cadet Command states that GBR assignments should never prevent 2Lts from serving in unfilled Camp LT assignments or the earliest unfilled OBC class. Two GBR scheduling guidelines implicitly exist in the MIP:

1. Schedule one of the Professor of Military Science preferences to the GBR assignment, when possible.
2. Maximize the number of days (up to the 140 day limit) a GBR serves without leaving early OBC classes unfilled.

The next section of this chapter (pages 26-27) discusses guideline implementation.

B. MIP FORMULATION

1. Indices

a	cadet (SSN), (e.g., 000011111, 000022222, …);
b	basic branch, (AD, AG, …, TC);
g	OBC class (FY-sequence), (e.g., 98-001, 98-002, …);
l	camp location, (Lewis, Knox);
p	period (MMDD-MMDD), (e.g., 0601-0715, 0608-0722,…);
r	region, (1,2,4);
s	duty status designation, (IA , AD);
	and
u	university (FICE code), (e.g., 001111, 001234, …).

2. Index Sets

$SetA_r$	Set of cadets *a* graduating from universities in region *r*;
	and
Camp	Set of cadets *a* who desire to serve in Camp LT assignments.

3. Given Data (units)

$campassign_{l,p}$	Number of Camp LT assignments at camp location *l*, in period *p* (cadets);
$campend_{l,p}$	Date when Camp LT assignment ends at camp location *l*, in period *p* (days);
$campstart_{l,p}$	Date when Camp LT assignment starts at camp location *l*, in period *p* (days);

$classnum_{b,g}$	For basic branch *b*, an integer value given to each OBC class *g*. The integer values range from 1 to the number of OBC classes offered to cadets in basic branch *b*. The largest integer value is given to the first OBC class offered. Each subsequent OBC class receives an integer value of one less than the class before it (unitless) ;
$commission_a$	Date cadet *a* receives his/her commission (days);
$leavereq_a$	The number of days graduation leave cadet *a* requests (days);
$maxcadet_{l,r}$	The maximum number of cadets that can be scheduled to Camp LT assignments at camp location *l* who receive commissions from ROTC battalions or extension centers in region *r* (cadets);
$mincadet_{l,r}$	The minimum number of cadets that must be scheduled to Camp LT assignments at camp location *l* who receive commissions from ROTC battalions or extension centers in region *r* (cadets);
$obcstart_{b,g}$	Date basic branch *b* starts OBC class *g* (days);
penleave	Penalty assessed for each ungranted leave day; (slack day/ungranted graduation leave day);
penobc	Penalty assessed for each unfilled OBC class assignment (slack day/unfilled OBC assignment);
rewcamp	Reward given for scheduling a cadet to a Camp LT assignment who desires to serve as a Camp LT (slack days);
rewfactor	Adjustment factor which rewards proper implementation of GBR scheduling guidelines (slack days/(day*day of GBR service));
$slotavail_{b,g}$	Number of OBC assignments available in basic branch *b*'s OBC class *g* (cadets);
traveldays	Number of days allotted for travel between assignments. (days);
$wantcamp_a$	Cadet *a*'s desire to serve as a Camp LT (unitless);
	and
$wantgbr_a$	The Professors' of Military Science desire for cadet *a* to serve as the GBR. (day of GBR service)

4. Derived Data (equation)

$adslack_{a,b,g,l,p}$ The number of slack days AD cadet *a*, in basic branch *b*, accumulates before OBC class *g*, if scheduled to a Camp LT assignment at camp location *l*, in period *p*. (= $obcstart_{b,g}$ - $campend_{l,p}$ - traveldays);

$ialvnocmp_{a,b,g}$ The number of requested graduation leave days IA cadet *a*, in basic branch *b*, doesn't receive if he/she is scheduled for OBC class *g*.
(= max(0, $leavereq_a$ - ($obcstart_{b,g}$ - $commission_a$ - traveldays)));

$ialvnoget_{a,b,g,l,p}$ The number of requested graduation leave days IA cadet *a*, in basic branch *b*, with OBC class *g*, doesn't receive if he/she is scheduled for a Camp LT assignment at camp location *l*, in period *p*.
(= max(0, $leavereq_a$ - ($campstart_{l,p}$ - $commission_a$ - traveldays)));

$iaslack_{a,b,g}$ The number of slack days an IA cadet *a*, in basic branch *b*, accumulates if scheduled to OBC class *g*.
(= ($obcstart_{b,g}$ - $commission_a$) - ($leavereq_a$ - $ialvnocmp_{a,b,g}$) - traveldays);

and

$iaslackcmp_{a,b,g,l,p}$ The number of slack days an IA cadet *a*, in basic branch *b*, accumulates if scheduled to OBC class *g*, and is also scheduled as a Camp LT at camp location *l*, in period *p*.
(= ($obcstart_{b,g}$ - $campend_{l,p}$) + ($campstart_{l,p}$ - $commission_a$) - ($leavereq_a$ - $ialvnoget_{a,b,g,l,p}$) - 2*traveldays).

5. Binary Variables

$CADCAMPOBC_{a,b,g,l,p}$ 1 if cadet *a*, in basic branch *b*, is scheduled to OBC class *g*, and is also scheduled as a Camp LT at camp location *l*, in period *p*, 0 otherwise;

and

$CADETOBC_{a,b,g}$ 1 if cadet *a*, in basic branch *b*, is scheduled to OBC class *g*, 0 otherwise.

6. Non-Negative Variables

$SLACKSLOT_{b,g}$ The number of assignments unfilled in basic branch *b* at OBC class *g*.

7. Formulation

Minimize:

$$\sum_{a,b,g,l,p} (\text{iaslackcmp}_{a,b,g,l,p} * \text{CADCAMPOBC}_{a,b,g,l,p}) \qquad (1)$$

$$+ \sum_{a,b,g} (\text{iaslack}_{a,b,g} * \text{CADETOBC}_{a,b,g})$$

$$+ \sum_{a,b,g,l,p} (\text{adslack}_{a,b,g,l,p} * \text{CADCAMPOBC}_{a,b,g,l,p})$$

$$+ \sum_{a,b,g,l,p} (\text{ialvnoget}_{a,b,g,l,p} * \text{penleave} * \text{CADCAMPOBC}_{a,b,g,l,p})$$

$$+ \sum_{a,b,g} (\text{ialvnocmp}_{a,b,g} * \text{penleave} * \text{CADETOBC}_{a,b,g})$$

$$+ \sum_{b,g} (\text{classnum}_{b,g} * \text{penobc} * \text{SLACKSLOT}_{b,g})$$

$$- \sum_{a,b,g} \text{rewfactor} * \text{obcstart}_{b,g} * \text{wantgbr}_{a} * \text{CADETOBC}_{a,b,g}$$

$$- \sum_{a \in \text{Camp}} \sum_{b,g,l,p} \text{rewcamp} * \text{CADCAMPOBC}_{a,b,g,l,p}$$

Subject To:

$$\sum_{a,b,g} \text{CADCAMPOBC}_{a,b,g,l,p} = \text{campassign}_{l,p} \qquad \forall l,p \qquad (2)$$

$$\sum_{a \in \text{SetA}_r} \sum_{b,g,p} \text{CADCAMPOBC}_{a,b,g,l,p} \geq \text{mincadet}_{l,r} \qquad \forall l,r \qquad (3)$$

$$\sum_{a \in \text{SetA}_r} \sum_{b,g,p} \text{CADCAMPOBC}_{a,b,g,l,p} \leq \text{maxcadet}_{l,r} \qquad \forall l,r \qquad (4)$$

$$\sum_{a,l,p} \text{CADCAMPOBC}_{a,b,g,l,p} + \sum_{a} \text{CADETOBC}_{a,b,g} + \text{SLACKSLOT}_{b,g} = \text{slotavail}_{b,g} \qquad \forall b,g \qquad (5)$$

$$\sum_{b,g,l,p} \text{CADCAMPOBC}_{a,b,g,l,p} + \sum_{b,g} \text{CADETOBC}_{a,b,g} = 1 \qquad \forall\, a \qquad (6)$$

8. Explanation of Objective Function and Constraints

Equation (1), the objective function, has units of slack days. *Penleave* and *penobc* convert ungranted graduation leave days and unfilled OBC assignments, respectively into this common unit. *Rewfactor* converts GBR scheduling guidelines into slack days. The objective function term

$$- \sum_{a,b,g} \text{rewfactor} * \text{obcstart}_{b,g} * \text{wantgbr}_a * \text{CADETOBC}_{a,b,g}$$

only rewards cadets *not* scheduled to a Camp LT assignment thereby reserving them for later consideration as a GBR.

Notice the direct relationship between the size of the reward and both the size of wantgbr_a and $\text{obcstart}_{b,g}$. Including wantgbr_a in the direct relationship instructs the MIP, all other things being equal, to schedule a lesser preferred cadet to a Camp LT assignment and save the more preferred cadet for future consideration as a GBR. Including $\text{obcstart}_{b,g}$ in the direct relationship instructs the MIP, all other things being equal, to schedule a lesser preferred cadet to fill the last available OBC assignment in an early class and save the more preferred cadet to fill an OBC assignment in a later OBC class. Together, these two terms accomplish the GBR guidelines discussed on page 21. The value chosen for *rewfactor* must remain small with respect to

penobc to ensure the MIP's priority remains filling early OBC class assignments.

Rewcamp converts the reward for proper Camp LT scheduling to units of slack days. The objective function term

$$\sum_{a \in Camp} \sum_{b,g,l,p} rewcamp * CADCAMPOBC_{a,b,g,l,p}$$

only rewards scheduling cadets to Camp LT assignments who desire to serve in those assignments.

Constraint (2) ensures all Camp LT assignments are filled. Constraints (3) and (4) ensure each ROTC region has an acceptable representation of Camp LTs at each camp location. Current policy dictates approximately 40% of Camp LTs at each location shall receive commissions from ROTC battalions and extension centers in Region 1, approximately 30% shall receive commissions from ROTC battalions and extension centers in Region 2, and approximately 30% shall receive commissions from ROTC battalions and extension centers in Region 4. The minimum tolerance for these percentages is plus or minus 5 percent.

Constraint (5) determines the number of unfilled assignments in each OBC class. Because each basic branch has more OBC assignments than cadets, there will always be some unfilled OBC classes. Cadet Command desires to fill the earlier OBC classes, when possible. The objective function term

$$\sum_{b,g} (classnum_{b,g} * penobc * SLACKSLOT_{b,g})$$

accomplishes this goal by penalizing early unfilled OBC class assignments more than later unfilled OBC class assignments.

Constraint (6) schedules all cadets for exactly one OBC class and no more than one Camp LT assignment. Sufficient OBC assignments exist to meet this constraint.

C. OBJECTIVES OF PROGRAMMING CODE FOR GBR SCHEDULING

The programming code subsequent to the MIP schedules cadets to GBR assignments. MCTDY has four objectives in this phase:

1. Maximize the number of universities which receive GBRs.
2. Reduce the total slack days developed in the MIP.
3. Maximize the number of days the GBR serves at each university.
4. Consider Professor of Military Science preferences.

Cadet Command prefers scheduling IA cadets to GBR assignments because an opportunity cost exists when scheduling an AD cadet as the GBR if an IA cadet is also available. Consider the following two points:

1. If not scheduled as a GBR, IA cadets can accumulate slack days from after their graduation leave until they start their OBC class. Scheduling an IA cadet as a GBR, reduces the number of slack days (Objective 2 of

the post-processing programming code) by the number of days he/she serve as a GBR.

2. If not scheduled as a GBR, AD cadets do not accumulate slack days between the commissioning ceremony and OBC class. There can not be a reduction in slack days if Cadet Command assigns an AD cadet as a GBR.

The opportunity cost equals the number of slack days that would be reduced by assigning the IA cadet vice the AD cadet as the GBR.

"Equivalent length of GBR service" accounts for Cadet Command's preference to schedule IA cadets as GBRs. "Equivalent length of GBR service" also accounts for the Professor of Military Science GBR preferences (Objective 4 of the post-processing programming code). The Professor of Military Science expresses his/her preference by the number of extra days of GBR service he/she believes the cadet is worth. At each university, Cadet Command schedules the cadet with the maximum equivalent length of GBR service as the GBR. The next section shows the precise method for computing equivalent length of GBR service.

D. SCHEDULING CADETS TO GBR ASSIGNMENTS

1. Given Data (units)

$commission_a$ Date cadet *a* receives his/her commission (days);

$startobc_a$ The date cadet *a* starts his/her OBC class. This is output of the MIP (days);

traveldays — Number of days allotted for travel between assignments; (days)

and

$wantgbr_a$ — The desire of the Professor of Military Science for cadet *a* to serve as the GBR. (equivalent days of GBR service)

2. Data Derived in Pseudo Code (units)

$equgbrdays_{u,a}$ — The equivalent length of GBR service of cadet *a* at university *u* (equgbrdays);

$highest_u$ — The maximum equgbrdays of all cadets eligible for assignment as a GBR at university *u* (equgbrdays);

$maxunivgbr_u$ — The maximum equgbrdays of any IA cadet at university *u* (equgbrdays);

and

$slacklost_u$ — The number of slack days for the IA cadet having the maxunivgbr at university *u*. (slack days);

3. Data Derived from MIP (equation)

$gbrdays_a$ — The number of days cadet *a* could serve as a GBR if selected to fill the assignment at his/her university. (equgbrdays)
(= min(140, ($startobc_a$ - $commission_a$ - traveldays)).

4. Pseudo Code:

```
For each ( university(u),
   maxunivgbr_u = 0;
   For each ( IA cadet a at university u who is both
        recommended to serve as a GBR and who isn't selected
        for a Camp LT assignment,
        IF( ( gbrdays_a + wantgbr_a) > maxunivgbr_u )
                  maxunivgbr_u = gbrdays_a + wantgbr_a;
                  slacklost_u = gbrdays_a;
        ); {end if}
   );
);


For each ( university (u),
     highest_u = 0;
     For each (cadet a at university u who is both
          recommended to serve as a GBR and who isn't selected
          for a Camp LT assignment,
          IF( cadet is IA,
               equgbrdays_u,a = gbrdays_a + wantgbr_a
          ); {end if}
          IF( cadet is AD,
              equgbrdays_u,a = gbrdays_a + wantgbr_a - slacklost_u;
          ); {end if}
          IF( (equgbrdays_u,a > highest_u ),
               highest_u = equgbrdays_u,a;
          ); {end if}
     );
);
```

These two loops determine $highest_u$ for each university. The cadet whose $equgbrdays_{u,a}$ equals the $highest_u$ serves as the GBR at his/her respective university. Notice that the formulation computes $equgbrdays_{u,a}$ differently between IA and AD cadets. This difference reflects the opportunity cost for selecting an AD cadet over the IA cadet with the maxunivgbr.

E. MCTDY IMPLEMENTATION

MCTDY uses GAMS for model generation and the IBM Optimization Subroutine Language (OSL) solver. Cadet Command plans to run MCTDY before and perhaps after each scheduling conference. MCTDY's output before the conference should help determine the number of assignments the Army ROTC desires for each OBC class. At the conference, Cadet Command can use these numbers to negotiate assignments with USMA, OCS, Army Reserve, Army National Guard, Marine Corps, and foreign military representatives. If Cadet Command does not receive the desired number of OBC assignments, they may run MCTDY using the number of OBC assignments actually acquired.

IV. INPUT DATA AND COMPUTATIONAL RESULTS

A. DATA CONTAINED IN INPUT TABLES

This section provides insight into the data contained in each of MCTDY's three required input tables. Table 2 lists examples of data contained in the cadet information table. The ROTC battalions' and extension centers' staffs provide Cadet Command with each cadet's social security number, commissioning date, desire to serve as a Camp LT, and requested number of days graduation leave. The Professor of Military Science also provides his/her desire to have each cadet serve as the GBR.

Cadet	$commission_a$	$wantcamp_a$	$leavereq_a$	$wantgbr_a$
000011111	132	1	30	16
000022222	129	0	0	11
000033333	145	1	30	6
000044444	119	0	0	0
000055555	135	0	0	11

Table 2. Examples of data found in the cadet information table on each cadet's social security number, commissioning date, desire to serve as a Camp LT, and requested number of days graduation leave. The Professors of Military Science also provide their desire to have each cadet serve as the GBR.

Table 3 lists examples of data contained in the camp information table. The staffs at Ft. Lewis and Ft. Knox send Cadet Command the various assignment periods and the required number of Camp LT assignments for each assignment period.

Camp Location. Period	$campstart_{l,p}$	$campend_{l,p}$	$campassign_{l,p}$
KNOX .0608-0721	158	201	12
KNOX .0624-0727	172	207	51
KNOX .0518-0729	137	209	44
LEWIS.0511-0818	130	229	1
LEWIS.0528-0725	147	205	28

Table 3. Examples of data found in the camp information table on Camp LT assignment periods at each summer camp location and the required number of assignments for each period.

Table 4 lists sample information contained in the OBC class information table. The staffs at each OBC training location send Cadet Command the OBC class start dates and the number of assignments available in each OBC class.

Basic Branch.OBC Class	$slotavail_{b,g}$	$obcstart_{b,g}$	$classnum_{b,g}$
AD.98-002	53	38	3
AR.98-004	17	39	18
FA.98-002	41	25	11
FI.98-002	9	208	3
SC.99-001	58	305	5

Table 4. Examples of data found in the OBC class information table on the number of assignments available in each OBC class, the OBC class start date, and $classnum_{b,g}$ as defined in the MIP.

B. OVERVIEW OF MCTDY TEST DATA

To test MCTDY's performance, Cadet Command provided information for cadets receiving commissions between 03 January and 31 September 1998. The data includes 2,828 cadets from 16 different basic branches and 270 ROTC battalions and extension centers, 463 different Camp LT assignments in 41 different periods at both camp locations, and 146 different OBC classes. Figure 3 shows the distribution of cadets receiving commissions from each basic branch during this period of time.

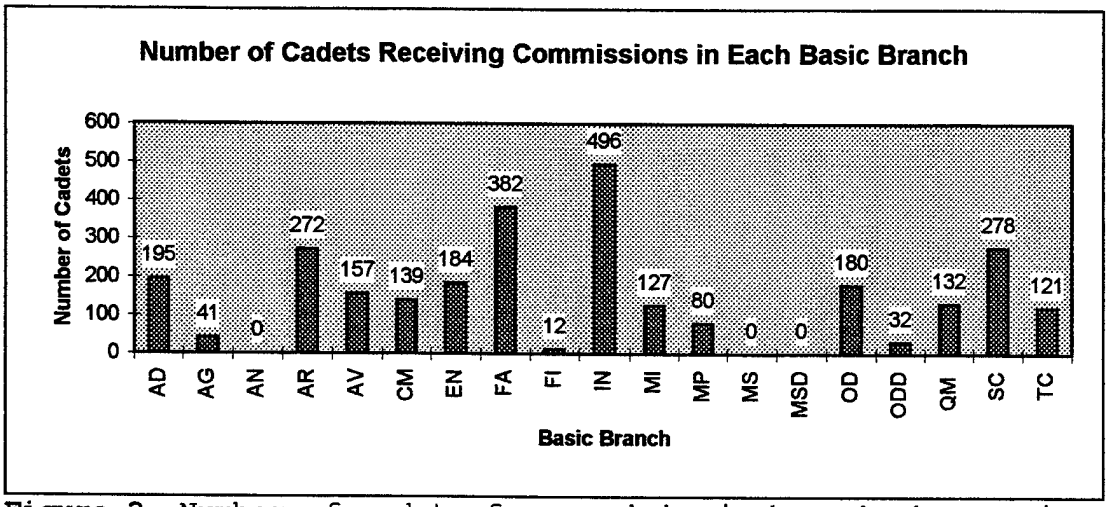

Figure 3. Number of cadets from each basic branch who receive commissions between 03 January and 31 September 1998.

Figure 4 shows the number of cadets who receive commissions each month, and Table 5 provides additional information on the cadets receiving commissions during this time period. Table 5 includes the assumption of seven days travel for cadets before all Camp LT and OBC class assignments. This travel assumption can cause

a difference between the number of slack days computed by MCTDY and the true number of slack days.

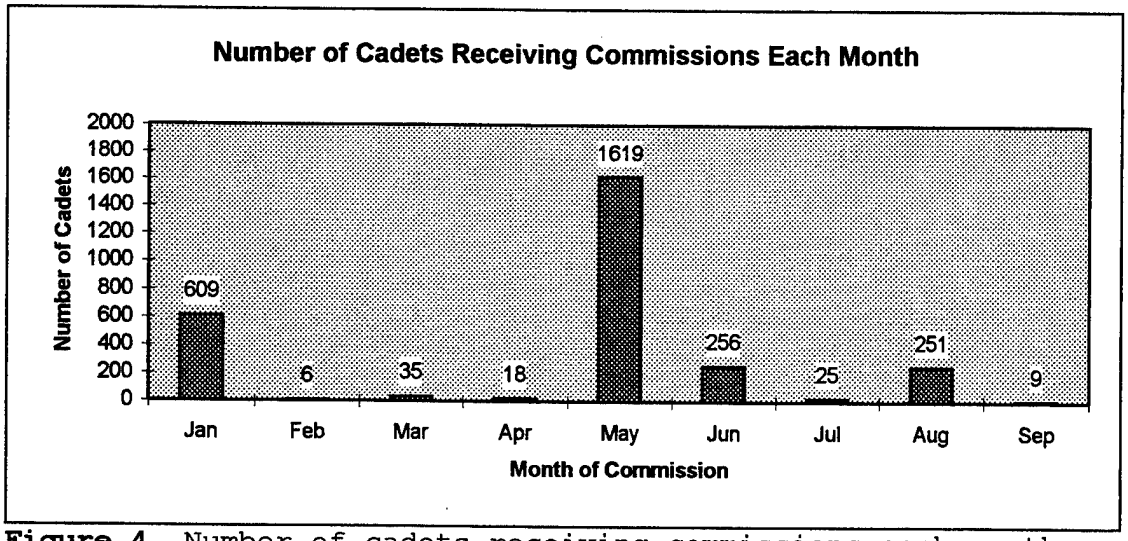

Figure 4. Number of cadets receiving commissions each month between 03 January and 31 September 1998.

Number of IA cadets	1,315
Number of AD cadets	1,513
Assumed graduation leave requested by IA cadets	30
Assumed travel days (non-Puerto Rico)	7
Assumed travel days (Puerto Rico)	150
Number who are eligible for a GBR assignment	1,225
Number who want to serve as Camp LT	564
Cadets from Region 1	1,151
Cadets from Region 2	901
Cadets from Region 3	776

Table 5. Additional information on cadets receiving commissions between 03 January and 31 September 1998.

The average length of the 41 different periods at both summer camps is 57 days. The shortest period is 35 days and the longest period is 106 days. All periods start between early May and early July and end between early July and late August. The OBC classes start at fairly regular intervals from mid-January 1998 through mid-March 1999. To determine an approximate interval between OBC class start dates in each basic branch, divide 15 months (January 1998 - March 1999) by the number of classes offered in each basic branch (Table 1, page 5).

C. COMPUTATIONAL RESULTS

MCTDY ran on an IBM RS/6000 Model 595 Workstation. The MIP contains approximately 3,100 constraints, 517,000 binary variables, and 2,000,000 non-zero elements. The generation time for this MIP is approximately 28 minutes and the execution time is 45 minutes.

The penalty and reward coefficients for *penslack*, *penleave*, *penobc*, *rewfactor*, and *rewcamp* influence the schedule MCTDY develops. It is therefore important to determine the coefficients that yield results matching Cadet Command's scheduling objectives (page 11). The six primary measures of performance (MOP) for meeting these scheduling objectives are:

1. the average number of slack days per cadet,
2. the number of universities that receive a GBR,
3. the average number of days each GBR serves,

4. the percentage of requested graduation leave days granted to IA cadets,
5. the number of unfilled OBC assignments in early OBC classes, and
6. the percentage of Camp LT assignments filled by cadets who request that assignment.

Seven model runs are performed to determine the sensitivity of the MOPs to varying reward and penalty coefficients. Each of the seven experiments performed has a unique scheduling emphasis. Table 6 shows the coefficients used in the different experiments. Experiment 1 tries to find the combination of coefficients that provides the best overall schedule. Experiment 2 uses the same coefficients as experiment 1 but maximizes the objective function. Experiment 2's "worst case schedule" provides an idea of the range of results that can occur. Experiment 3 focuses on minimizing the number of slack days. Experiment 4 focuses on maximizing the number of graduation leave days IA cadets receive. Experiment 5 focuses on reducing the number of unfilled assignments in early OBC classes. Experiment 6 focuses on maximizing the percentage of Camp LTs who desire to serve in that assignment. Experiment 7 focuses on maximizing the length of GBR service.

Coefficients	Exp 1	Exp 2	Exp 3	Exp 4	Exp 5	Exp 6	Exp 7
penslack	1	1	**100**	1	1	1	1
penleave	1	1	1	**50**	1	1	1
penobc	40	40	40	40	**200**	40	40
rewcamp	30	30	30	30	30	**60**	30
rewfactor	.002	.002	.002	.002	.002	.002	**.1**

Table 6. Penalty and reward coefficients used in seven experiments. Each of the seven experiments has a unique scheduling emphasis. Table 7 shows the results from using these coefficients.

Table 7 shows the primary MOPs resulting from each experiment. Table 8 shows the number of universities in each experiment that receive a preferred cadet as the GBR.

Primary MOPs	Exp 1	Exp 2	Exp 3	Exp 4	Exp 5	Exp 6	Exp 7
Average Slack Days	4.61	74.21	**3.72**	14.84	4.81	4.62	4.62
Universities with GBRs	199	202	205	**228**	205	215	200
Ave. GBR service (days)	119.7	**134.4**	122.7	106.6	118.8	128.7	120.9
Requested graduation leave days granted (%)	75.3	85.0	64.6	**99.6**	73.2	74.8	75.3
Unfilled early OBC assignments	136	568	137	166	**135**	413	136
Percentage of Camp LT assignments filled by cadets requesting assignment	87.9	1.3	70.0	59.0	**97.2**	74.7	87.9

Table 7. Primary MOPs from seven experiments. The first experiment is the baseline from which all others are compared. The second experiment is the worst case schedule. Each of the remaining five experiments focuses on improving one of the MOPs. The penalty and reward coefficients used in Table 6 yield the results of the corresponding experiments in this table.

Secondary MOP	Exp 1	Exp 2	Exp 3	Exp 4	Exp 5	Exp 6	Exp 7
First choice	93	130	93	111	91	114	90
Second choice	44	37	47	64	49	46	46
Third choice	25	17	24	25	26	21	27
Fourth choice	13	5	13	16	15	15	12
Fifth choice	13	6	16	6	12	10	13
Another choice	11	7	12	6	12	9	12

Table 8. The number of universities receiving a preferred cadet as the GBR. The penalty and reward coefficients used in Table 6 yield the results of the corresponding experiments in this table.

Table 9 shows the percentage of Camp LTs at each camp location who receive commissions from each region.

	Exp 1	Exp 2	Exp 3	Exp 4	Exp 5	Exp 6	Exp 7
Percent Camp LTs at Ft. Knox from region 1	36.7	42.1	46.7	43.4	35.5	46.1	34.9
Percent Camp LTs at Ft. Knox from region 2	28.3	30.7	29.7	32.3	30.7	27.3	28.9
Percent Camp LTs at Ft. Knox from region 4	35.0	27.2	23.6	24.3	33.8	26.6	36.2
Percent Camp LTs at Ft. Lewis from region 1	37.7	46.1	38.6	40.4	35.7	39.1	38.4
Percent Camp LTs at Ft. Lewis from region 2	33.3	26.3	31.2	32.5	31.3	30.1	33.3
Percent Camp LTs at Ft. Lewis from region 4	29.0	27.6	30.2	27.1	33.0	30.8	28.3

Table 9. Percentage of Camp LTs at each camp location who receive commissions from ROTC battalions and extension centers in each region. The penalty and reward coefficients used in Table 6 yield the results of the corresponding experiments in this table.

V. CONCLUSIONS AND FUTURE ENHANCEMENTS

MCTDY offers Cadet Command a much faster and cost-effective method of scheduling ROTC cadets to Camp LT, GBR, and OBC assignments. For 2,828 cadets receiving commissions in 1998, MCTDY produces face-valid, cost-effective results in approximately 73 minutes. Direct comparisons between MCTDY and manual schedules are not made but the $15 million TDY cost difference between the 1998 schedule with the best balance of all measures of performance (experiment 1) and the "worst case" schedule (experiment 2) illustrates the potential impact of MCTDY.

MCTDY is very adaptive to policy changes. For example, during the development of MCTDY, the Camp LT policy changed. The previous policy limited 2Lts from regions 1 and 4 to serve as Camp LTs at Ft. Lewis, and limited 2Lts from region 2 to serve as Camp LTs at Ft. Knox. Only two lines of code in a GAMS input file were changed to accommodate the current policy.

MCTDY also serves nicely as a decision-aid to policy makers. For example, only 75.3% of the requested graduation leave days are granted to IA cadets in experiment 1. Cadet Command may consider a policy which guarantees each IA cadet the full amount of requested graduation leave. Experiment 4 grants nearly all requested graduation leave to IA cadets (99.6%) but, when compared to experiment 1, the average slack days per cadet increases by more than 10. The policy change increases TDY

costs by over $2 million. With MCTDY, decision makers remain informed of policy change consequences.

Two modeling enhancements exist for MCTDY. The first is to use actual travel days between duty assignments instead of the universally assigned seven days. Since not all assignment transfers require seven days, MCTDY currently eliminates some feasible scheduling options from consideration. The second enhancement is to minimize TDY costs, not just slack days, by using tables with TDY costs at each assignment location. The information required for both enhancements can be found in the Joint Federal Travel Regulations (JFTR) manual.

MCTDY could accommodate future analysis on the following issues:

1. including the cost of 2Lt pay and allowances to determine the overall savings to the Army, not just Cadet Command.
2. meeting gender requirements in Camp LT assignments,
3. meeting requirements for 2Lts with Journalism or Computer Science degrees in Camp LT assignments,
4. requiring Camp LTs at Fort Knox to have attended the basic Camp as a cadet, and
5. limiting the number of AD 2Lts in each basic branch who start their first assignment during a fiscal year.

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